Developments of New Concept Approach Slabs for Improvements of Bridge Approaches

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ABSTRACT

Void under approach slabs happens due to consolidation of back-filling material and settlement caused by vehicles vibration in bridge approaches. When storm water on the surface of bridges flows inter-space between approach slabs and abutments and runs underneath approach slabs, it causes loss of the back-filling material. Loss of the back-filling material and void under approach slabs cause deflection and differential settlement of approach slabs and make road's ride quality worse. Therefore, this research wishes to develop new concept approach slabs shape that can minimize deflection of approach slab even if loss of the back-filling material and void under approach slabs come about. Developed new concept approach slabs, that is Abutment Integral Approach Slabs, may minimize that the storm water on roads permeates into the back-filling material and contribute in the elevation of ride quality on roads.

1. INTRODUCTION

Bridge approaches are weakness area in which faulting and settlement and crack on approach slabs and bridge deck is happened frequently by much factors including settlement of the foundation soils, poor compaction of backfill material, loss of backfill material by erosion, incongruent drainage system as well as effect by slabs' design and construction that is formed by reinforced concrete structures. Moreover, impact depending on the faulting and settlement of bridge approach is connoting many problems that increase cost and time for maintaining roads, and aggravate driver's vehicle control, and cause vehicle damage, and make bridge deck impaired by snow plough cars. (Figure 1) shows deflection that happens to approach slabs in bridge approaches and voids that are created under approach slabs [4]. This research proposed Abutment Integral Approach Slab that abutment and approach slabs are integrated and consequently, problems of bridge approaches can be minimized by Abutment Integral Approach Slab even if consolidation, settlement and loss happen in backfill material. Abutment Integral Approach Slab's applicability was examined explanatorily as comparing behavior of normal approach slabs and Abutment Integral Approach Slab. In addition, structural performance elevation was conducted by arranged PS tendons in Abutment Integral

Approach Slab. Finally, the way for application was presented in accordance with examination about length and thickness of Abutment Integral Approach Slab.

Figure 1. Void underneath approach slabs and deflection

2. NEW CONCEPT APPROACH SLABS

This research was also developed new concept approach slab named the Abutment Integral Approach Slab to improve the ride quality and solve the problems of bridge approaches. The Abutment Integral Approach Slab is not only integrated abutment and approach slab but also restored deflection through arranged PS tendons due to losing backfill material and removed the negative bending moment near the abutment as following (figure 2).

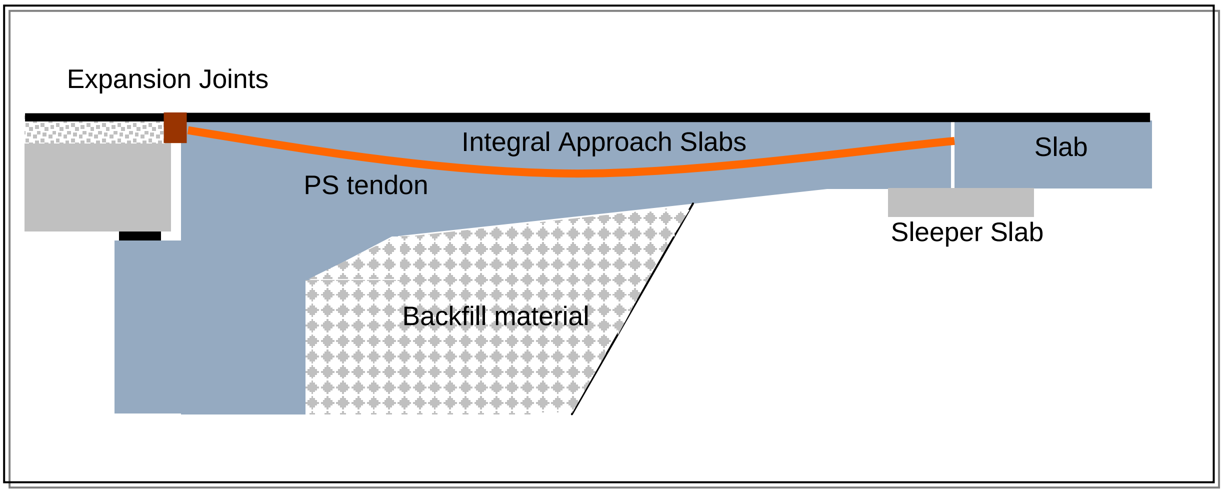
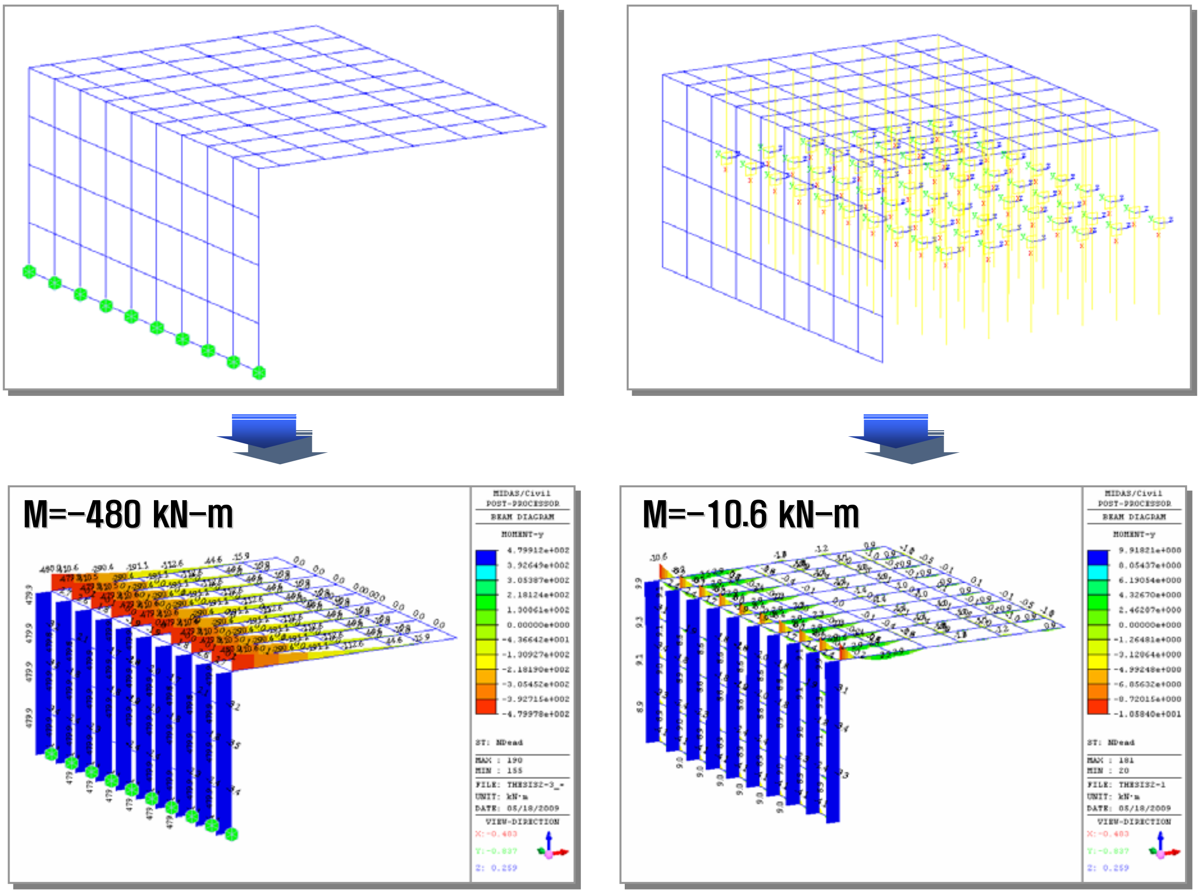


Figure 2. Key map of Abutment Integral Approach Slab

And this study was performed to analyze the bending moment where was arranged simple cantilever structure and spring cantilever structure such as backfill material. Because the shape of Abutment Integral Approach Slab was like the cantilever, the negative bending moment was forecasted at the edge of approach slab as following (figure 3). In the case of spring cantilever

structure, the negative bending moment at the edge of approach slab was reduced 1/50 and therefore Abutment Integral Approach Slab can be regarded to apply at bridge approaches.



(a) without backfill material (b) without backfill material

Figure 3. The bending moment of cantilever structure by backfill material

3. ANALYSIS INVESTIGATION

3.1 Outline

This study aims to analyze applicable possibility of Abutment Integral Approach Slab to the bridge approaches through the analysis of comparison between the normal approach slabs which have simple supporting point and Abutment Integrated Approach Slab. At the same time, this study was also suggested the plans that reduce deflection and remove negative bending moment by arranged PS tendons, when the backfill material was lost and settled.

3.2 Modeling

To analyze the behavior between Abutment Integral Approach Slab and normal approach slabs, the modeling was progressed. There used the approach slab which is of 6m length, 10m width

in highway bridge with two lines(one way). Only parapet of abutment was modeled for convenience. The design strength of abutment and approach slab was 24MPa and the crack stress was 1.2MPa. The structural analysis was performed by Midas program which was finite element method, the slab and abutment was modeled by beam element. In the case of backfill material, the modeling was progressed Elastic Link element allows only compressive force at the surface spring support which bearing capacity factor, K was 20kgf/cm^3. Generally the approach slab is connected with abutment by simple support. Therefore the structural analysis of normal approach slab was progressed to model approach slab and the structural analysis of Abutment Integral Approach Slab was progressed to model including parapet of abutment. Even if, the haunch which is arranged at the edge is regard to connect two members is more desirable, for comparing behavior between two types of approach slab, Abutment Integral Approach Slab was modeled without haunch. Applied load was considered the load of surface course and subbase, in the case of prestress was also considered the load of prestress.

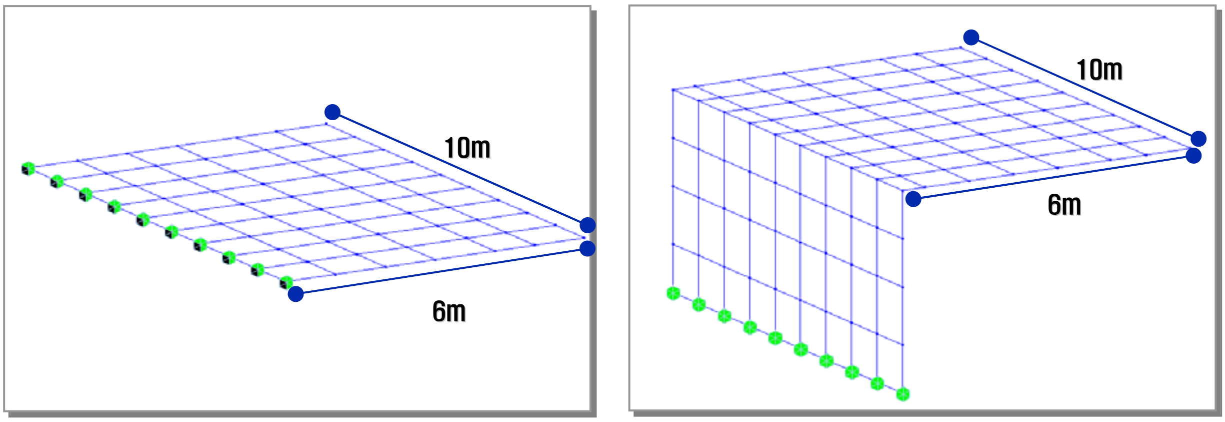
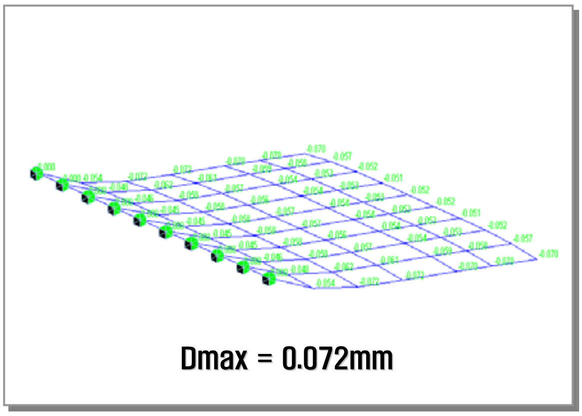
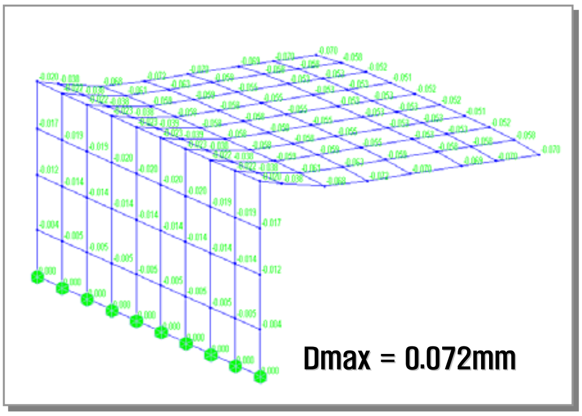


Figure 4. Approach slab Modeling

3.3 The Investigation for Applicability of Abutment Integral Approach Slab

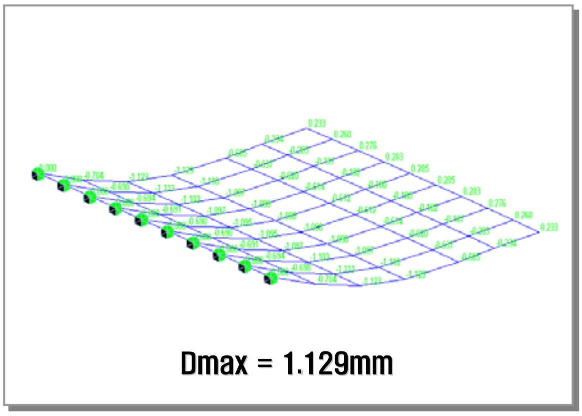
The behavior of normal approach slab depending on variation of backfill material and Abutment Integral Approach Slab were compared dividing two types. The backfill of each types are modeled by Elastic Link. First type is supposed that backfill is lost almost 70% but the backfill of second type has no loss. Generally, normal approach slab is designed that 70% of length is supposed one-way slab which is simply supported. Therefore, the comparison was also supposed that backfill material has lost 70% and that lost was expressed removing Elastic Link. [1][2] The result of analysis for deflection is exposed as following (figure 5). In the case of normal approach slab and Abutment Integral Approach Slab, the deflection which has lost 0% backfill materials, were very similar. On the other hand, in the case of Abutment Integral Approach Slab, the deflection which has lost 70% backfill materials, were reduced almost 56% compared for normal approach slab.

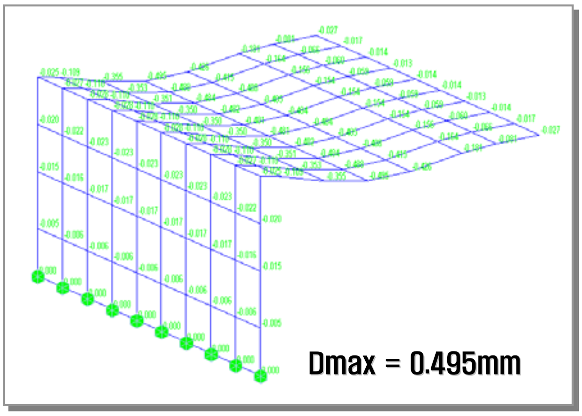




(a) Normal approach slab + 0% loss

(b) Abutment Integral Approach Slab + 0% loss



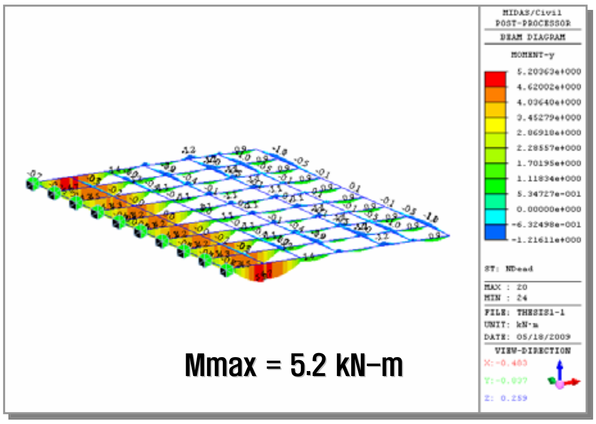


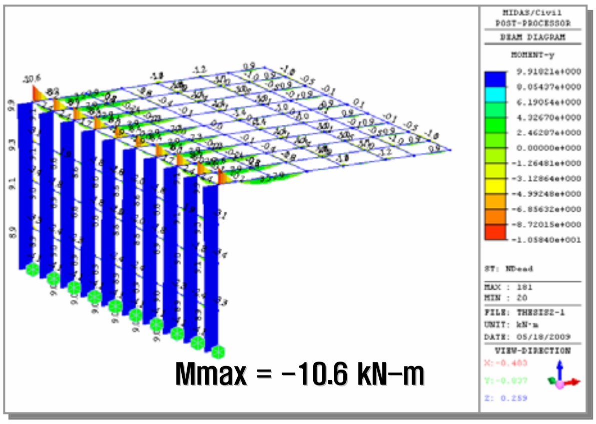
(c) Normal approach slab + 70% loss

(d) Abutment Integral Approach Slab + 70% loss

Figure 5. Deflection diagram of approach slab

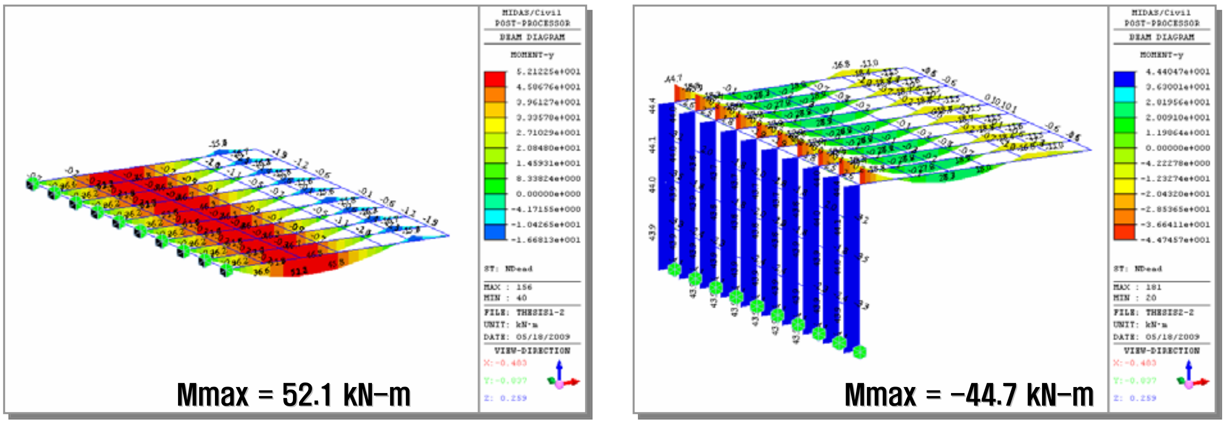
The result of analysis for bending moment is exposed as following (figure 6). In the case of the backfill materials have lost 0%, the bending moment of each slab could be found a little. But the bending moment which has lost 70% backfill materials, was huge increased at both slabs.





(a) Normal approach slab + 0% loss

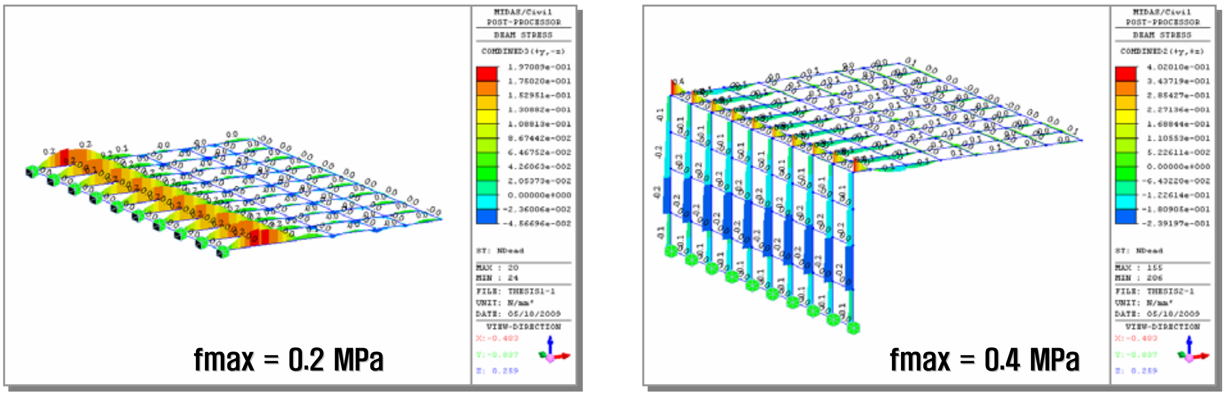
(b) Abutment Integral Approach Slab + 0% loss



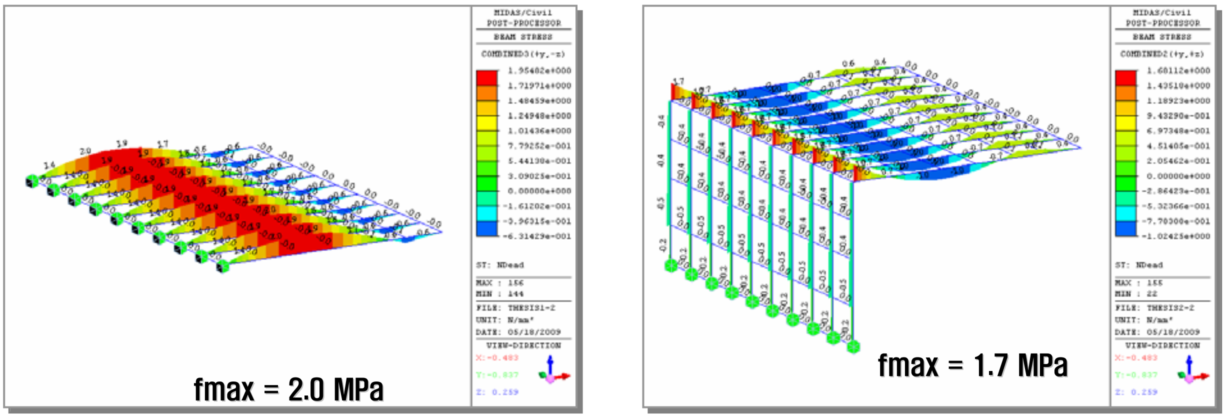
(c) Normal approach slab + 70% loss (d) Abutment Integral Approach Slab + 70% loss

Figure 6. Bending moment diagram of approach slab

The bending tensile stress depending on bending moment is exposed as following (figure 7). In the case of the backfill materials have lost 0%, the bending tensile stress of each slab could be found a little so the crack did not happen but the bending tensile stress which has lost 70% backfill materials, were huge increased at both of slab and could be found crack. Thus this research suggested, if the backfill material has lost 70%, the structural behavior of each slab could be found some problems.



(a) Normal approach slab + 0% loss (b) Abutment Integral Approach Slab + 0% loss



(c) Normal approach slab + 70% loss (d) Abutment Integral Approach Slab + 70% loss

Figure 7. Bending tensile stress diagram of approach slab

3.4 Examination of PS tendons' arrangement

If approximate 70% loss in backfill material come about, bending tensile stress (1.7MPa) that is happened to approach slabs exceeds crack stress (1.2MPa). Therefore, it is necessary to reduce bending moments. The PS tendons in Abutment Integral Approach Slab were arranged with 1m space in the transverse direction to reduce bending moments, as shown in (figure 8). The PS tendons having sectional area of 138.7 ㎟ made use of unbounded steels that were 1900MPa ultimate strength and 1600MPa yield strength. The PS tendons were prestressed by the post-tensioning method, and applied 1330MPa tensile stress that is 70% of ultimate strength.

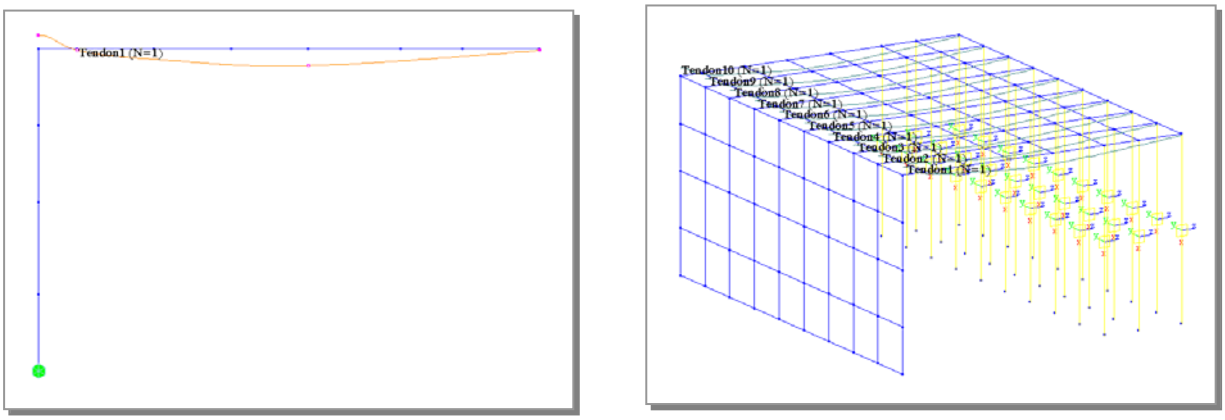
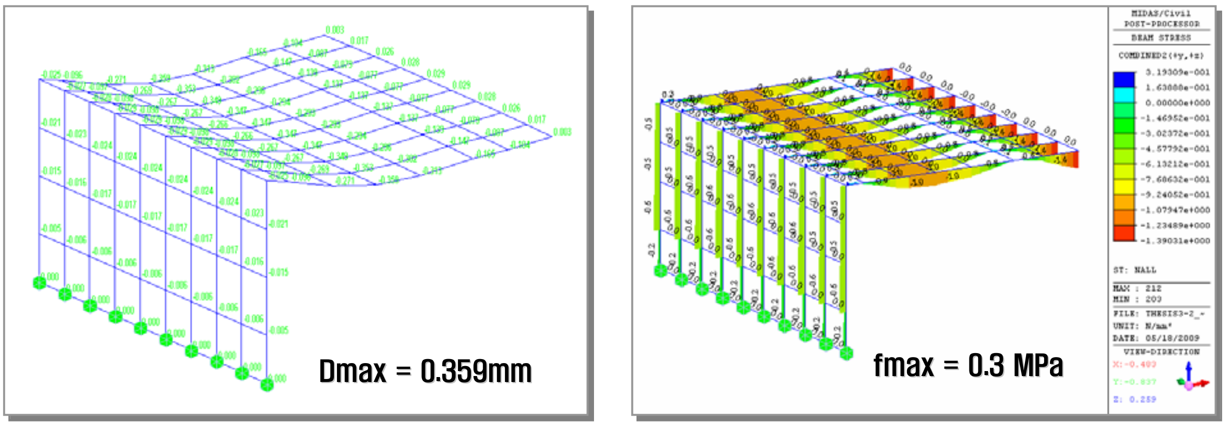


Figure 8. PS tendons' layout

According to alignment of PS tendons in Abutment Integral Approach Slab, deflection was decreased about 27% and bending tensile stress varied from 1.7MPa to 0.3MPa. Therefore, crack problems can be solved.



(a) Deflection diagram with PS tendons (b) Bending tensile stress with PS tendons

Figure 9. Deflection and bending tensile stress in Abutment Integral Approach Slab with PS tendons.

4. ANALYZING THE BEHAVIOR OF ABUTMENT INTEGRAL APPROACH SLAB

As length and thickness of approach slabs became the variables, it was examined Abutment Integral Approach Slab. Also, analyzing the behavior of Abutment Integral Approach Slab was conducted to present the way for application. The material characteristic is equal to that used at chapter 3, but the haunch of 880mm thickness installed at the point that abutment and approach slabs meet in Abutment Integral Approach Slab and the haunch of 400mm thickness installed at the point that is away 1000m in road direction. Also, the modeling of whole abutment and the lateral soil pressure of backfill material were considered. The loss of backfill material was analyzed supposing that the loss of backfill material under all approach slabs is 4.2m length. Basis modeling for conducting the behavior of Abutment Integral Approach Slabs is as following (figure 10).

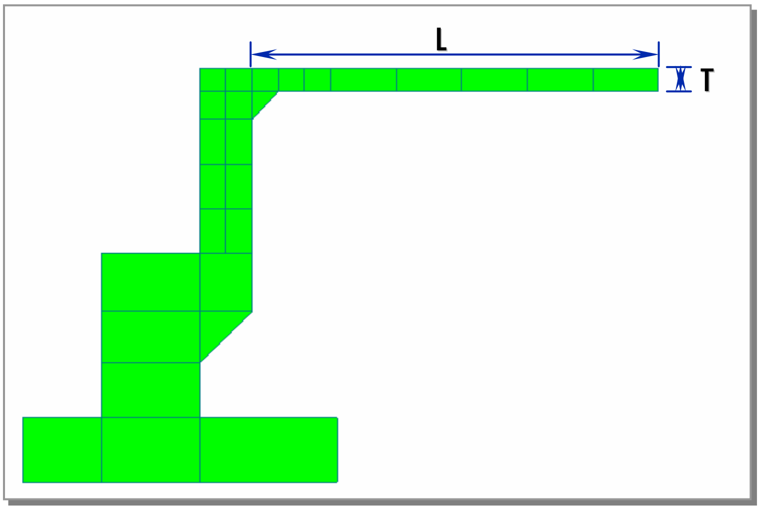


Figure 10. Modeling for the behavior of Abutment Integral Approach Slab

4.1 Behavior due to variation of length

The length of approach slab measured at point that the abutment and the approach slab meet as shown in figure 10. The structural behavior of Abutment Integral Approach Slab structure was analyzed while the length of approach slabs was increasing. Also, the length of approach slab was examined by varying 6m, 9m, 12m, and 15m. The result of analysis displayed to (figure 11). In the (figure 11), it indicates that there are not much change in deflection and bending tensile stress even if approach slabs' length in Abutment Integral Approach Slabs changes. Besides, the bigger value of bending tensile stress that was caused in the upper side of approach slabs appeared in a road more than in a abutment. Since the crack stress was larger than maximum bending tensile stress, it suggested that the crack did not happen. While installing haunch in the boundary between the abutment and the approach slab, the negative bending moment reduced sharply and bending tensile stress also decreased as much as cracks did not happen without alignment of PS tendons. Therefore,

improving the shape of haunch is effective in Abutment Integral Approach Slab and the control of negative bending moment that could be appeared in the loss of backfill material is available.

It suggests that more than 6m length of approach slabs that shown in "Road Design Manual" does not make structural problems.

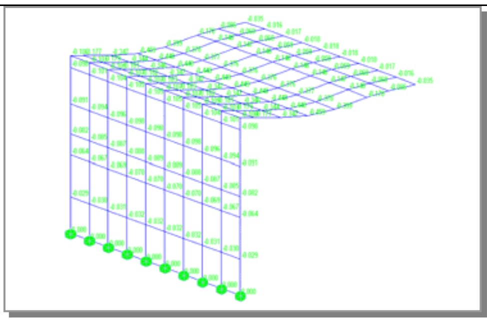
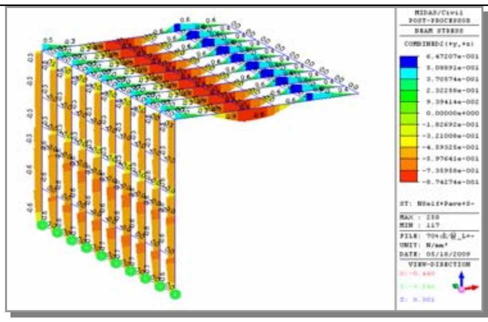
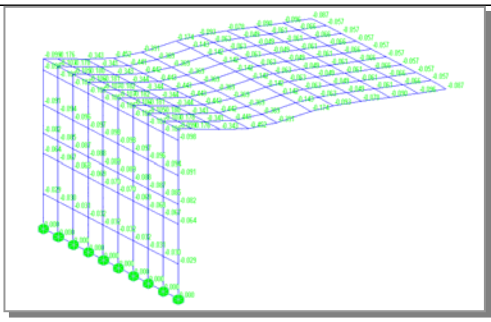
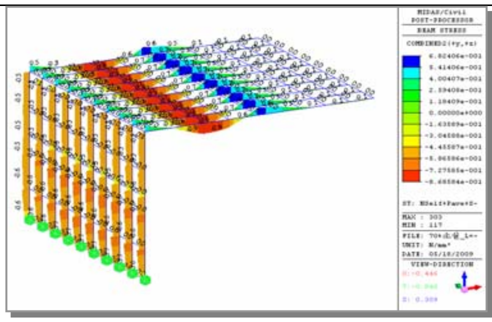
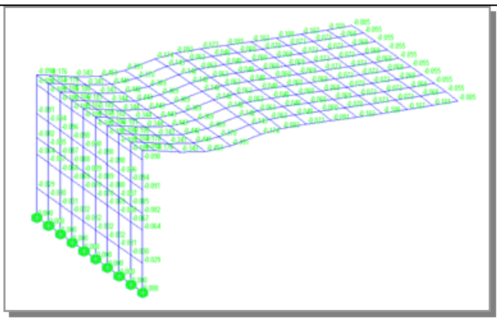
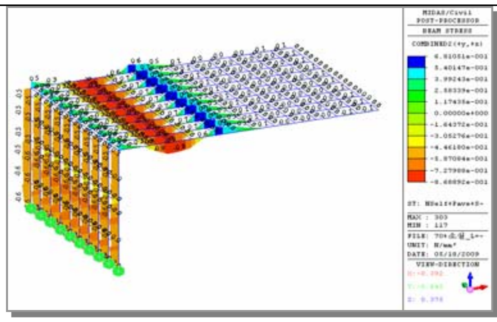
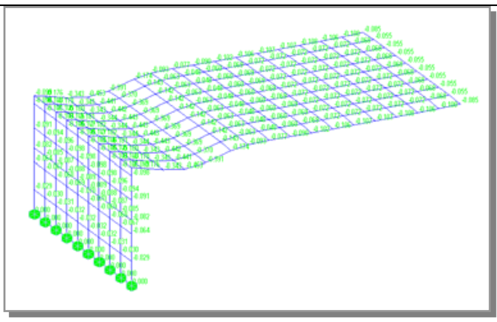
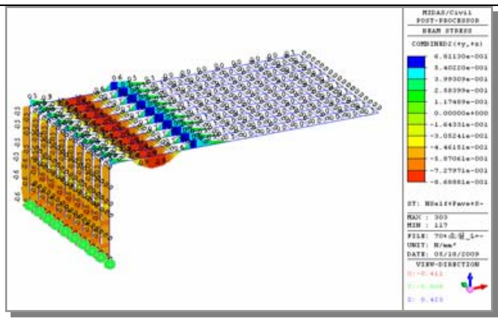
variables	Deflection diagram	Bending tensile stress diagram
L=6m, t=400mm	 Dmax = 0.459mm	 fmax = 0.64MPa
L=9m, t=400mm	 Dmax = 0.452mm	 fmax = 0.68MPa
L=12m, t=400mm	 Dmax = 0.453mm	 fmax = 0.68MPa
L=15m, t=400mm	 Dmax = 0.453mm	 fmax = 0.68MPa

Figure 11. Behavior due to approach slabs length

4.2 Behavior due to variation of thickness

The thickness of approach slabs that is used at the present is mostly 400mm. Since the behavior changes as abutment and approach slabs are embodied, the beginning point of haunch was fixed to 880mm, and the thickness varied by 200mm, 300mm and 400mm from the ending point of haunch for investigating behavior change. As shown on (Figure 11) and (Figure 12), it indicates that deflection and bending tensile stress increase as thickness becomes thin in case the length of approach slabs is 6m.

When approach slabs thickness varied from 400mm to 300mm, 18.5% for deflection, 50% for bending tensile stress were increased. On the other hand, in case approach slabs thickness varied from 400mm to 250mm, 33.8% for deflection, 87.5% for bending tensile stress were increased. As a result, bending tensile stress reaches to crack stress and the problems of serviceability are exposed in case approach slabs thickness is 250mm. Therefore, approach slabs' thickness is to be more than 300mm.

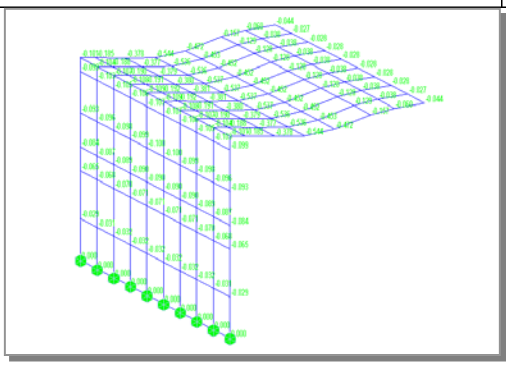
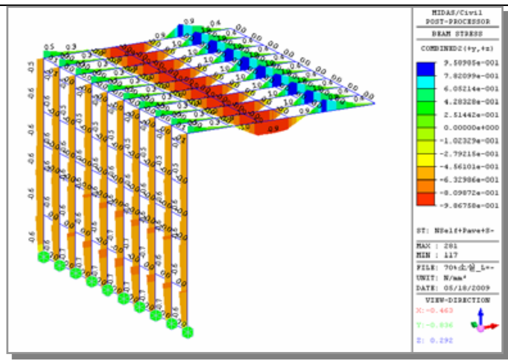
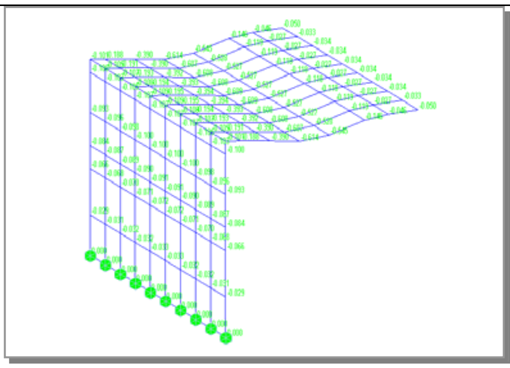
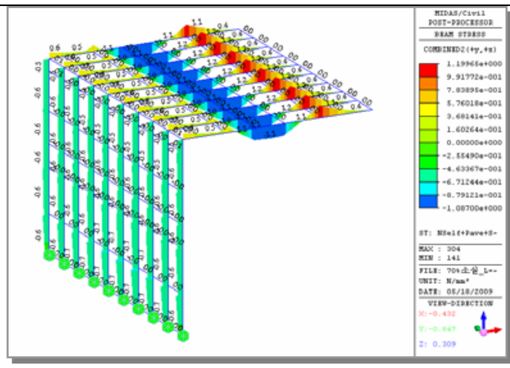
variables	Deflection diagram	Bending tensile stress diagram
L=6m, t=300mm	 Dmax = 0.544mm	 fmax = 0.96MPa
L=6m, t=250mm	 Dmax = 0.614mm	 fmax = 1.20MPa

Figure 12. Behavior due to approach slabs thickness

5. CONCLUSIONS

This research proposed Abutment Integral Approach Slab that abutment and approach slabs are embodied and further, deflection and faulting that happen to bridge approaches can be minimized by new concept Abutment Integral Approach Slab. The Abutment Integral Approach Slab's applicability was examined explanatorily compared behavior of normal approach slabs and Abutment Integral Approach Slab. The PS tendons' application is studied to prepare the case that negative bending moment happens greatly to Abutment Integral Approach Slab and deflection and bending tensile stress is done while approach slabs' length and thickness changed. As Abutment Integral Approach Slab was examined supposing about 70% backfill material disappeared, about 56% deflection and about 15% bending tensile stress decreased when abutment and approach slabs are embodied. Therefore, it showed that the structural behavior improved according to integrate abutment and approach slabs. Even though bending tensile stress caused by negative bending moment exceeded crack stress, PS tendons and haunch installed in Abutment Integral Approach Slab make bending tensile stress decreased and so it is possible to control crack stress. The applicability of Abutment Integral Approach Slab was preformed by analyzing structural behavior in case abutment and approach slabs are embodied. As a result, it was confirmed that haunch installed in the boundary between abutment and approach slabs achieved important role fairly. Above all, research for haunch shape may have to be achieved continuously considering execution and structural performance hereafter.

ACKNOWLEDGMENTS

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